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Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/018

INFORMATION NEEDED IN SUPPORT OF THE IDENTIFICATION OF THE HABITAT NECESSARY FOR THE SURVIVAL AND RECOVERY OF ROCKY MOUNTAIN RIDGED MUSSEL (*GONIDEA ANGULATA*)

G. angulata in lacustrine habitat with a substrate mixture of sand, silt, and mud. (Photo: Roxanne Snook)

Figure 1. Distribution of Rocky Mountain Ridged Mussel in British Columbia, Canada.

Context:

When an aquatic species is listed on Schedule 1 of the Species at Risk Act (SARA) as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO) is required to identify and protect habitat required for the survival and recovery of the species, which is linked to the population and distribution objectives established in a Recovery Strategy.

The Rocky Mountain Ridged Mussel is a freshwater bivalve mollusc that reaches the northern extent of its range within the Okanagan Valley in southern British Columbia. The species has been decreasing in numbers and extent across its North American Range and is currently listed as a species of Special Concern under SARA. As such, population and distribution objectives have not been identified in a Recovery Strategy. However, the species has been assessed by the Committee on the Status of Wildlife in Canada (COSEWIC) as Endangered. If it is subsequently re-listed as Endangered under SARA, it is expected that critical habitat will be identified in a Recovery Strategy.

In support of the anticipated requirements under SARA, DFO Science has been asked to undertake a habitat assessment for Rocky Mountain Ridged Mussel, based on the national Guidelines for the Identification of Critical Habitat for Aquatic Species at Risk (DFO 2015). The identification of critical

habitat is based on the best available information and is provided in the form of scientific advice (a peer-reviewed Research Document and Scientific Advisory Report) which may be used to inform the identification of critical habitat in a Recovery Strategy or an Action Plan for this species.

SUMMARY

- In Canada, Rocky Mountain Ridged Mussel (*G. angulata)* is found only in the Okanagan Valley where it is considered to be at the northern extent of its range.
- Rocky Mountain Ridged Mussel (RMRM) has been assessed by COSEWIC as endangered. If listed under the *Species at Risk Act*, critical habitat will have to be identified for the species.
- Habitat necessary for the survival and recovery of the species has been determined based on a bounding box approach, including the geo-spatial identification and a description of associated biophysical functions, features and attributes.
- Two distinct habitat features (lacustrine and riverine) have been recommended for this species, as both support completion of all life stages of RMRM.
- Key habitat attributes for RMRM include water quality, water depth and site slope, exposure/fetch, substrate size and embeddedness, available food supply and availability of a host fish to support development and transportation of larvae.
- Sculpin have been determined to be the most likely host fish (other possible hosts include Longnose Dace, Leopard Dace and Northern Pikeminnow); however the specific host fish species and their required abundance is unknown.
- Historical occupancy data, habitat suitability modeling and recent observations were used to identify areas that would meet the criteria for critical habitat. However, only areas that have been surveyed since 2005 and have RMRM present are recommended as critical habitat at this time.
- Activities identified as most likely to destroy critical habitat of RMRM include: land development, channel alterations and dredging, water level changes in the Okanagan Valley and introduction of invasive species.
- The main knowledge gaps that need to be addressed for this species include: determination of minimum viable population size, confirmation of the host fish species and associated ranges and migration patterns, flow measurements at areas with and without mussel beds and determination of the maximum sediment load tolerance for RMRM.

INTRODUCTION

Freshwater mussels are arguably one of the most endangered groups of animals in North America. The Rocky Mountain Ridged Mussel *(Gonidea angulata)* is an endangered freshwater mussel in the family Unionidae. Its northern distribution lies within the Okanagan Valley in British Columbia (B.C.), Canada, and the species is decreasing in extent and numbers across its North American range. *G. angulata* is considered an imperiled species in B.C. (B.C. Conservation Data Centre 2015 a,b), and it has been assessed as endangered in 2010 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2010). *G. angulata* is currently listed as a species of special concern under the *Species at Risk Act* (SARA). When a species is listed as endangered under SARA critical habitat must be identified using the best available information.

Critical habitat is defined in SARA as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species". For aquatic species at risk, SARA defines habitat as "... spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced." [s. 2(1)].

A bounding box approach (as described by DFO, 2015) has been chosen as the most appropriate method to identify the extent of habitat required in order to meet population and distribution recovery objectives for *G. angulata* in the Okanagan Valley, where the species presently occurs. As additional areas are explored, these may be recommended as critical habitat. Recent research is used to support identification of habitat features and attributes that are vital to support the biophysical functions of this species, and to provide a geographic description of critical habitat.

ASSESSMENT

The areas within which critical habitat for *G. angulata* occurs are shown in Figure 1. The waterbodies in which *G. angulata* have been observed in the Okanagan Valley include the Okanagan River, Okanagan Lake, Skaha Lake, Vaseux Lake, Osoyoos Lake and Park Rill Creek. It should be noted that the Okanagan Lake Dam, Okanagan Falls, McIntyre, and Zosel dams regulate water levels and outflow from Okanagan Lake, Skaha, Vaseux, and Osoyoos Lakes, respectively, with numerous weirs existing along the Okanagan River.

G. angulata occur throughout the Okanagan River, which flows from the southern end of Okanagan Lake and connects all of the Okanagan Valley lakes. Densities of *G. angulata* vary in each of the three segments of the Okanagan River in B.C.; in general, relatively high densities are found at sites in channelized sections of the Okanagan River while the species is nearly absent from natural sections of the river. There are very few *G. angulata* found in the first segment (extending from the south end of Okanagan Lake to the north end of Skaha Lake through Penticton). The highest densities of *G. angulata* in the second segment (south of Skaha Lake to the north of Vaseux Lake through Okanagan Falls) inhabit the mouth of the river emerging from Vaseux Lake. The highest overall river densities of *G. angulata* occur in the third segment of the Okanagan River (south of Vaseux Lake to the north of Osoyoos Lake through Oliver) from Oliver to the river mouth entering Osoyoos Lake.

The bounding box approach required identification of essential habitat functions, features and attributes for each life-stage of *G. angulata* to identify patches of potential critical habitat within the 'bounding box', as defined by occupancy data (collected 2005-2015) for the species. Table 1 summarizes the best available knowledge of the functions, features and attributes needed for each life-stage of *G. angulata* in the Okanagan Valley.

G. angulata use two distinct habitat features: lacustrine and riverine. Some important attributes are the same within each environment, while others are different, yet perform the same functions. Availability of food, specific substrate sizes, host fish (species and abundance), and water quality ranges within the species tolerance have been identified as essential attributes in both lacustrine and riverine habitat. Riverine systems which have low hydraulic variability and stable substrates and lacustrine systems which have a bench or low slope and optimal site exposure (i.e., effective/total fetch) are also important critical habitat attributes for *G. angulata*.

Due to increased survey efforts in 2013-15, many new *G. angulata* sites have recently been discovered in the Okanagan Valley; these are not considered to be new populations established since the 2009 surveys.

*Table 1. Essential functions, features and attributes of critical habitat for each life-stage of the G. angulata *, in the Okanagan River Valley.*

Life Stage	Function	Feature(s)	Attribute(s)	Shared Attribute(s) of Features
Adult	Spawning and brooding	Lacustrine habitat	• Site exposure (i.e., effective fetch) 6-20 km • Bench or low (0-20%) slope/site inclination • Availability of boulders (> 256 mm) and coarse cobbles (128 to 256 mm) (Stanton et al. 2012) • Polygon width of 80 m from shoreline elevation of 343 m (TRIM)	• Availability of food supply • Availability of high sand (0.6-2mm) occurrence (>20 %), medium-high substrate embeddedness (> 25%) which may contain a mixture of sand, silt, mud, and organics (Stanton et al. 2012, Snook 2015) • Water quality parameters (oxygen >3-6 ppm and pH 5.6 – 9.5) within the natural range of variation • Water temperatures > 14°C for conglutinate release period • Availability of appropriate host fish (both species and abundance); sculpin (*Cottus* sp.) and possibly additional species
	Reproduction (Glochidia released as conglutinates from May-July)			
	Spawning and brooding	Riverine Habitat	• Stable banks of depths 0.5 – river bottom • Low hydraulic variability (Davis et al. 2013), i.e. channelized river, glide • Free flowing water available year-round • Flow refuge (in the form of boulders (> 256 mm) or coarse cobbles (128 to 256 mm) in	

Life Stage	Function	Feature(s)	Attribute(s)	Shared Attribute(s) of Features
	Reproduction (Glochidia released as conglutinates from May-July)		stable substrate), especially below weir structures	
Juvenile (post excystment/ detachment from host)	Growth to reproductive stage (6-7years in Okanagan)	Lacustrine habitat	• Site exposure (i.e. effective fetch) 6-20 km • Bench or low (0-20%) slope/site inclination • Availability of boulders (> 256 mm) and coarse cobbles (128-256 mm) (Stanton et al. 2012) • Polygon width of 80 m from shoreline elevation of 343 m (TRIM)	• Availability of food supply • Availability of sand (0.6-2 mm) occurrence (>20 %), medium-high substrate embeddedness (> 25%) which may contain a mixture of sand, silt, mud, and organics (Stanton et al. 2012, Snook 2015) • Water quality parameters (oxygen >3-6 ppm and pH 5.6 – 9.5) within the natural range of variation • Availability of appropriate host fish (both species and abundance) i.e. sculpin (*Cottus* sp.) and possibly additional species
		River Habitat	• Flow refuge (in the form of boulders (> 256 mm) or coarse cobbles (128-256 mm) in stable substrate), especially below weir structures • Low hydraulic variability (Davis et al. 2013), i.e. channelized river, glide • Free flowing water available year-round • Stable banks of depths 0.5 m – river bottom	

Life Stage	Function	Feature(s)	Attribute(s)	Shared Attribute(s) of Features
Juvenile-Adult	Foraging	Lacustrine habitat	• Site exposure (i.e. effective fetch) 6-20 km • Bench or low (0-20%) slope/site inclination (Snook 2015) • Availability of high sand (0.6-2 mm) occurrence (>20 %), medium-high substrate embeddedness (> 25%) which may contain a mixture of sand, silt, mud, and organics (Stanton et al. 2012, Snook 2015) • Availability of boulders (> 256 mm) and coarse cobbles (128 to 256 mm) (Stanton et al. 2012) • Polygon width of 80 m from shoreline elevation of 343 m (TRIM)	• Availability of food supply • Availability of sand (0.6-2 mm) occurrence (>20 %), medium-high substrate embeddedness (> 25%) which may contain a mixture of sand, silt, mud, and organics (Stanton et al. 2012, Snook 2015) • Water quality parameters (oxygen >3-6 ppm and pH 5.6 – 9.5) within the natural range of variation
		River Habitat	• Stable banks of depths 0.5 m – river bottom • Free flowing water available year-round • Flow refuge (in the form of boulders (> 256 mm) or coarse cobbles (128 to 256 mm) in stable substrate) where fine sediments accumulate, especially below weir structures • Low hydraulic variability (Davis et al. 2013), i.e. channelized river, glide	

*where known or supported by existing data

Activities Likely to Destroy Critical Habitat

When critical habitat is identified, SARA requires that "examples of activities that are likely to result in its destruction will be provided". The activities most likely to destroy the critical habitat properties were therefore identified and information on the extent and consequences of these activities provided.

As defined by DFO (2015):

> "Destruction of critical habitat would result if any part of the critical habitat were degraded, either permanently or temporarily, such that it would not serve its functions when needed by the species. Destruction may result from single or multiple activities at one point in time or cumulative effects of one or more activities over time."

Activities that are likely to permanently or temporarily destroy critical habitat for *G. angulata* are described in Table 2, *include, but are not limited to the following:*

- land development for resource extraction or private homes, which alters sediment inputs into nearby water sources;
- enhancement of habitat for other species (e.g. salmonids), which can alter the features in which *G. angulata* are established;
- removal of invasive aquatic macrophytes (e.g. root extraction from rototilling), which alters substrate, increases turbidity, and crushes benthic dwelling organisms;
- cumulative impacts of dock construction within mussel beds, which may have a significant effect on their habitat;
- dredging of locations with heavy sediment, detritus, or sewage output resulting in removal of substrate, and of mussels;
- dramatic water level changes resulting from low snow pack accumulation, drought, high water extraction, and energy demand;
- introduction of invasive species, such as Smallmouth Bass and *Dreissena sp.*, which can alter food web structure; and
- release of deleterious substances and other point pollution scenarios which can cause immediate die-off of mussels, or non-point pollution impacts which may take years to detect if recruitment is reduced.

Table 2. Activities likely to destroy critical habitat.

Threat	Activity	Effect -Pathway	Function Affected	Feature Affected	Attribute Affected
Activities that generate significant sediment inputs	Work in or around critical habitat with improper sediment and erosion control (e.g. installation of bridges, culverts), run-off from urban, residential, agricultural and industrial land use, use of industrial equipment, cleaning or maintenance of bridges, drains or other structures without proper mitigation.	Improper sediment and erosion control or mitigation can cause increased turbidity and sediment deposition. Significant sediment influx into the river or lake could impair the osmoregulatory capacity of *G. angulata* and obstruct host fish from coming into contact with conglutinates.	Spawning and Brooding	River & Lacustrine Habitat	• Water quality parameters (oxygen and pH) within the natural range of variation • Sedimentation within natural range of variation • Availability of high sand (0.6-2 mm) occurrence (>20 %), medium-high substrate embeddedness (> 25%) which may contain a mixture of sand, silt, mud, and organics (Stanton et al. 2012, Snook 2015) • Stable banks of depths 0.5 – 5 m (River only) • Suitable habitat for host fish
Alteration of habitat for human use	Disturbance or loss of littoral and riverine habitat (e.g. rototilling of Eurasian watermilfoil).	Rototilling is an insufficient method in complete EWM eradication. Disrupts and may cover preferred habitat. Can bury and crush mussels. Cutting or trimming is recommended as an alternative method in sites with *G. angulata*. Dock construction	Spawning and brooding Reproduction Growth Foraging	River & Lacustrine Habitat	• Water quality parameters (oxygen, temperature and pH) within the natural range of variation • Sedimentation within natural range of variation • Availability of high sand (0.6-2 mm) occurrence (>20 %), medium-high substrate embeddedness (> 25%) which may contain a mixture of sand, silt, mud, and organics (Stanton et al. 2012, Snook 20015) • Bench or low (0-20%) slope/site inclination Water depths 0.5 m – 5 m along

Threat	Activity	Effect -Pathway	Function Affected	Feature Affected	Attribute Affected
	Installation and maintenance of docks, pilings, groynes, piers. Dredging, grading, excavation, structure removal and Construction of dams and/or barriers. Alteration of river bed composition and shape for salmon enhancement.	can crush or bury mussels with piling placement. Groynes can alter water movement and disturb or cover preferable substrate. River alterations for salmon habitat resulting in reduction of available suitable habitat for *G. angulata*.			littoral zone (Lacustrine Habitat) • Availability of food supply • Availability of appropriate host fish (both species and abundance), sculpin (*Cottus* sp.) and potentially other species • Host fish foraging synchronized with conglutinate release, within hours - days • Suitable habitat for host fish • Flow refuge (in the form of boulders (> 256 mm) or coarse cobbles (128 to 256 mm) in stable substrate), especially below weir structures (River only) • Stable banks of depths 0.5 – 5 m (River only) • Low hydraulic variability (Davies et al. 2013), i.e. channelized river, glide (River only)
Water withdrawals and/or impoundment	Water-level management (e.g. through dam operation) or water extraction activities (e.g. for irrigation), that causes dewatering of habitat.	Water fluctuations greater than natural variability could alter water flow in the Okanagan River and Okanagan Lakes. Reduced water levels can isolate and strand mussels above water level (Stanton et al. 2012) or in a highly	Spawning and brooding Reproduction Growth Foraging	River & Lacustrine Habitat	• Water quality parameters (oxygen, temperature and pH) within the natural range of variation • Flow refuge (in the form of boulders (> 256mm) or coarse cobbles (128 to 256 mm) in stable substrate), especially below weir structures (River only) • Stable banks of depths 0.5 - 5m (River only) • Low hydraulic variability (Davis et al. 2013), i.e. channelized river, glide (River only) • Water depths 0.5m - 5m along

Threat	Activity	Effect -Pathway	Function Affected	Feature Affected	Attribute Affected
		exposed position, vulnerable to wave action, weathering, desiccation, or predation. Changes to river flow can affect sediment deposits (altering preferred substrates), and change water temperature. Juveniles are especially vulnerable to scouring.			littoral zone (Lacustrine only) • Availability of food supply • Availability of appropriate host fish (both species and abundance), sculpin (*Cottus* sp.) and potentially other species • Suitable habitat for host fish
Introduction of invasive species through human activities	Inadvertent or deliberate introduction of non-native species (e.g. *Dreissena* sp); opening of dams and fish ladders that allow species transfers (e.g. Smallmouth Bass).	Modification of predator/prey relationships.	Spawning and brooding Reproduction Growth Foraging	River & Lacustrine Habitat	• Availability of appropriate host fish (both species and abundance), sculpin (*Cottus* sp.) and possibly additional species • Suitable habitat for host fish • Host fish foraging synchronized with conglutinate release, within hours - days • Availability of food supply • Destruction of substrate; *Dreissena* sp. can create own substrate and suffocate native freshwater mussels

Threat	Activity	Effect -Pathway	Function Affected	Feature Affected	Attribute Affected
Release of deleterious substances and excessive nutrient input through groundwater and/or surface flows from point or non-point sources	Release of urban and industrial pollution into habitat including: storm-water runoff from existing and new developments, residential septic seepage, over-application of fertilizer (commercial or residential) and improper nutrient management (e.g. organic debris, wastewater, animal waste, septic system and municipal sewage).	Polycyclic Aromatic Hydrocarbons (PAHs) do not readily dissolve in water but will bind with organic material and can be deposited in the sediment. This could affect adult feeding and metamorphosis, as well as larvae development and host fish availability and habitat. Eutrophication resulting in algal blooms reducing light penetration and water clarity, changing water chemistry, increasing sedimentation rates and altering food web structure.	Spawning and brooding Reproduction Growth Foraging	River & Lacustrine Habitat	• Water quality parameters (oxygen and pH) within the natural range of variation • Few or no added pollutant • Availability of appropriate host fish (both species and abundance) i.e. sculpin (*Cottus* sp.) and possibly additional species • Availability of food supply

Sources of Uncertainty

Several sources of uncertainty and knowledge gaps have been identified. Habitat ranges or limitations associated with sedimentation and interstitial oxygen requirements are unknown for this species. This information may be important to determine the potential impacts of further erosion in the Okanagan River watershed associated with foreshore development, and increased water treatment output with increasing human population pressures. Their thermal tolerance and tolerance of dessication are also unknown.

There is uncertainty regarding habitat requirements related to water flow and movement at sites with *G. angulata*. Since *G. angulata* are passive filter feeders, feeding and respiration are accomplished from loading of the sites with food in well circulated waters. Minimum, maximum, and optimal water flow at and movement at sites are unknown habitat parameters for this species.

Unknown elements in this species life history include identifying whether *G. angulata* are short-term (tachytictic) brooders (with spawning and glochidial release occurring in the same season) or long-term (bradytictic) brooders, and identifying their required host fish species.

The ecological role of riparian habitat is unknown for *G. angulata*, in terms of quantity and quality necessary in lakes and rivers. Presumably, riparian habitat has multiple vital functions for *G. angulata*. Since *G. angulata* are passive filter feeders, specific ranges of quantity and quality of detritus and riparian habitat are likely important attributes for this species.

Recommendations for further research

Further studies to support the full identification of critical habitat for *G. angulata* are recommended. Additional or refined critical habitat recommendations can be made from by expanding the current analysis to include lacustrine habitat; specifically, projecting the random forests model (Snook 2015) across Okanagan Lake (and other lakes in the Okanagan River watershed when bathymetric data becomes available). This may predict sites where *G. angulata* occur, but have not yet been surveyed, or locate sites with optimal habitat for this species where it hasn't yet dispersed.

It is also recommended that sites which lack *G. angulata* occurrence, but have suitable habitat features be considered by management in association with objectives linked to distribution, survival, and recovery goals. These sites may be appropriate for critical habitat designation once more information becomes available on the recovery targets, and on the population's' ecology.

Finally, potential lacustrine and riverine critical habitat sites have been identified and spatially described by polygons using the Bounding Box Approach. Should this species be listed as endangered, sites with recently (2005-2015) confirmed occurrences are recommended for critical habitat designation. Advice on the extent of critical habitat required for this population cannot be provided because recovery targets have not been identified.

While the data used for this assessment is the best currently available, ground truthing with accurate G.P.S. is recommended for future mapping of critical habitat. Field surveys are recommended to confirm or disregard potential additional habitat sites identified during a recent modeling exercise undertaken by Snook (2015).

Further study related to *G. angulata* host fish species is recommended to improve understanding of their roles associated with juvenile recruitment, habitat connectivity, and threats to the population's recovery. Specifically, information regarding host fish migration (i.e. how far sculpin travel) is necessary to determine a projected temporal and spatial framework for

mussel distribution. Determination of additional host fish species and their ecological roles in terms of mussel recruitment, dispersal, bed connectivity and genetic variability in the population would address questions pertaining to population genetics and dispersal mechanisms.

CONCLUSIONS AND ADVICE

- Rocky Mountain Ridged Mussels are only found in the Okanagan Valley in Canada and are considered to be at the northern extent of their range.
- It was determined that there is sufficient information available to provide initial advice on critical habitat for the Rocky Mountain Ridged Mussel. Habitat necessary for survival and recovery of the species has been determined based on the Bounding Box approach that includes geo-spatial identification and associated functions, features and attribute.
- Life stage habitat attributes related to lacustrine and riverine habitat features were identified as both lacustrine and riverine habitat support completion of all life stages in Canadian waters.
- The key habitat attributes for RMRM include water quality, water depth and site slope, exposure/fetch, substrate size and embeddedness, available food supply and availability of a host fish to support development and transportation of larvae.
- Further information on the ecology of *G. angulata* host fish species, expansion of the habitat model to include lakes in the Okanagan watershed, and additional surveys are required in order to fully determine critical habitat for the species.
- Specific population and distribution targets are required to determine the sufficiency of the identified Critical Habitat for recovery of the species.

OTHER CONSIDERATIONS

A minimum viable population size is an unknown element in the management of this species (DFO 2011). Determining if the amount of proposed critical habitat is sufficient to maintain this population will become plausible, as more information becomes available on the recovery targets, and on the population's' ecology. Details such as if *G. angulata* are short-term (tachytictic) brooders, with spawning and glochidial release occurring in the same season or if they are long-term (bradytictic) brooders are unknown elements in this species life history. This information may be important for determining minimum or maximum temperatures required for the survival of the species in the event of changing climate conditions resulting in years of adverse environmental conditions.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 10-11, 2016 regional peer review on Information in support of the identification of critical habitat for Rocky Mountain Ridged Mussel (*Gonidea angulata*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ISSN 1919-5087
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Correct Citation for this Publication:

DFO. 2017. Information needed in support of the identification of the habitat necessary for the survival and recovery of Rocky Mountain Ridged Mussel (*Gonidea angulata*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/018.

Aussi disponible en français :

MPO. 2017. Information requise afin de désigner l'habitat nécessaire à la survie et au rétablissement de la gonidée des rocheuses (Gonidea angulata). Secr. can. de consult. sci. du MPO, Avis sci. 2017/018.